CONSTRUCTION METHOD AND PROJECT MANAGEMENT

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I. CONTRACT AND SPECIFICATION FOR CONSTRUCTION PROJECT

Construction Contract Agreement:

-is a written document between a property owner and a general contractor, specifying the construction, renovation, alteration or other work to be done on the property owner's home or land. This document outlines which parties will be engaged, the price to be paid, rights of party, and the date of construction will commerce and be completed.

-this agreement allows parties to put into writing the exact nature and details of the work to be performed and the responsibilities of each party throughout the course construction

- **Construction Pricing and Contracting**

Because of the unique nature of constructed facilities, it is almost imperative to have a separate price for each facility. The construction contract price includes the direct project cost including field supervision expenses plus the markup imposed by contractors for general overhead expenses and profit. The factors influencing a facility price will vary by type of facility and location as well. Within each of the major categories of construction such as residential housing, commercial buildings, industrial complexes and infrastructure, there are smaller segments which have very different environments with regard to price setting. However, all pricing arrangements have some common features in the form of the legal documents binding the owner and the supplier(s) of the facility. Without addressing special issues in various industry segments, the most common types of pricing arrangements can be described broadly to illustrate the basic principles.

- Competitive Bidding

The basic structure of the bidding process consists of the formulation of detailed plans and specifications of a facility based on the objectives and requirements of the owner, and the invitation of qualified contractors to bid for the right to execute the project. The definition of a qualified contractor usually calls for a minimal evidence of previous experience and financial stability. In the private sector, the owner has considerable latitude in selecting the bidders, ranging from open competition to the restriction of bidders to a few favored contractors. In the public sector, the rules are carefully delineated to place all qualified contractors on an equal footing for competition, and strictly enforced to prevent collusion among contractors and unethical or illegal actions by public officials.

Detailed plans and specifications are usually prepared by an architectural/engineering firm which oversees the bidding process on behalf of the owner. The final bids are normally submitted on either a lump sum or unit price basis, as stipulated by the owner. A lump sum bid represents the total price for which a contractor offers to complete a facility according to the detailed plans and

specifications. Unit price bidding is used in projects for which the quantity of materials or the amount of labor involved in some key tasks is particularly uncertain. In such cases, the contractor is permitted to submit a list of unit prices for those tasks, and the final price used to determine the lowest bidder is based on the lump sum price computed by multiplying the quoted unit price for each specified task by the corresponding quantity in the owner's estimates for quantities. However, the total payment to the winning contractor will be based on the actual quantities multiplied by the respective quoted unit prices.

- Negotiated Contracts

Instead of inviting competitive bidding, private owners often choose to award construction contracts with one or more selected contractors. A major reason for using negotiated contracts is the flexibility of this type of pricing arrangement, particularly for projects of large size and great complexity or for projects which substantially duplicate previous facilities sponsored by the owner. An owner may value the expertise and integrity of a particular contractor who has a good reputation or has worked successfully for the owner in the past. If it becomes necessary to meet a deadline for completion of the project, the construction of a project may proceed without waiting for the completion of the detailed plans and specifications with a contractor that the owner can trust. However, the owner's staff must be highly knowledgeable and competent in evaluating contractor proposals and monitoring subsequent performance.

Generally, negotiated contracts require the reimbursement of direct project cost plus the contractor's fee as determined by one of the following methods:

1. Cost plus fixed percentage
2. Cost plus fixed fee
3. Cost plus variable fee
4. Target estimate
5. Guaranteed maximum price or cost

The fixed percentage or fixed fee is determined at the outset of the project, while variable fee and target estimates are used as an incentive to reduce costs by sharing any cost savings. A guaranteed maximum cost arrangement imposes a penalty on a contractor for cost overruns and failure to complete the project on time. With a guaranteed maximum price contract, amounts below the maximum are typically shared between the owner and the contractor, while the contractor is responsible for costs above the maximum.

- **Speculative Residential Construction**

In residential construction, developers often build houses and condominiums in anticipation of the demand of home buyers. Because the basic needs of home buyers are very similar and home designs can be standardized to some degree, the probability of finding buyers of good housing units

within a relatively short time is quite high. Consequently, developers are willing to undertake speculative building and lending institutions are also willing to finance such construction. The developer essentially set the price for each housing unit as the market will bear, and can adjust the prices of remaining units at any given time according to the market trend.

❖ Force-Account Construction

Some owners use in-house labor forces to perform a substantial amount of construction, particularly for addition, renovation and repair work. Then, the total of the force-account charges including in-house overhead expenses will be the pricing arrangement for the construction.

❖ Contract Provisions for Risk Allocation

Provisions for the allocation of risk among parties to a contract can appear in numerous areas in addition to the total construction price. Typically, these provisions assign responsibility for covering the costs of possible or unforeseen occurrences. A partial list of responsibilities with concomitant risk that can be assigned to different parties would include:

- Force majeure (- this provision absolves an owner or a contractor for payment for costs due to "Acts of God" and other external events such as war or labor strikes)
- Indemnification (-this provision absolves the indemnified party from any payment for losses and damages incurred by a third party such as adjacent property owners.)
- Liens (-assurances that third party claims are settled such as "mechanics liens" for worker wages),
- Labor laws (- payments for any violation of labor laws and regulations on the job site),
- Differing site conditions (- responsibility for extra costs due to unexpected site conditions),
- Delays and extensions of time,
- Liquidated damages (- payments for any facility defects with payment amounts agreed to in advance)
- Consequential damages (-payments for actual damage costs assessed upon impact of facility defects),
- Occupational safety and health of workers,
- Permits, licenses, laws, and regulations,
- Equal employment opportunity regulations,
- Termination for default by contractor,
- Suspension of work,
- Warranties and guarantees.

ACTIVITY 1:

1. What is construction specification?

2. What is the importance of using contract agreement?

3. What should be included in the contract agreement?

❖ **Types of Construction Contracts**

While construction contracts serve as a means of pricing construction, they also structure the allocation of risk to the various parties involved. The owner has the sole power to decide what type of contract should be used for a specific facility to be constructed and to set forth the terms in a contractual agreement. It is important to understand the risks of the contractors associated with different types of construction contracts.

○ Lump Sum Contract

In a lump sum contract, the owner has essentially assigned all the risk to the contractor, who in turn can be expected to ask for a higher markup in order to take care of unforeseen contingencies. Beside the fixed lump sum price, other commitments are often made by the contractor in the form of submittals such as a specific schedule, the management reporting system or a quality control program. If the actual cost of the project is underestimated, the underestimated cost will reduce the contractor's profit by that amount. An overestimate has an opposite effect, but may reduce the chance of being a low bidder for the project.

- Unit Price Contract

In a unit price contract, the risk of inaccurate estimation of uncertain quantities for some key tasks has been removed from the contractor. However, some contractors may submit an "unbalanced bid" when it discovers large discrepancies between its estimates and the owner's estimates of these quantities. Depending on the confidence of the contractor on its own estimates and its propensity on risk, a contractor can slightly raise the unit prices on the underestimated tasks while lowering the unit prices on other tasks. If the contractor is correct in its assessment, it can increase its profit substantially since the payment is made on the actual quantities of tasks; and if the reverse is true, it can lose on this basis. Furthermore, the owner may disqualify a contractor if the bid appears to be heavily unbalanced. To the extent that an underestimate or overestimate is caused by changes in the quantities of work, neither error will affect the contractor's profit beyond the markup in the unit prices.

- Cost Plus Fixed Percentage Contract

For certain types of construction involving new technology or extremely pressing needs, the owner is sometimes forced to assume all risks of cost overruns. The contractor will receive the actual direct job cost plus a fixed percentage, and have little incentive to reduce job cost. Furthermore, if there are pressing needs to complete the project, overtime payments to workers are common and will further increase the job cost. Unless there are compelling reasons, such as the urgency in the construction of military installations, the owner should not use this type of contract.

- Cost Plus Fixed Fee Contract

Under this type of contract, the contractor will receive the actual direct job cost plus a fixed fee, and will have some incentive to complete the job quickly since its fee is fixed regardless of the duration of the project. However, the owner still assumes the risks of direct job cost overrun while the contractor may risk the erosion of its profits if the project is dragged on beyond the expected time.

- Cost Plus Variable Percentage Contract

For this type of contract, the contractor agrees to a penalty if the actual cost exceeds the estimated job cost, or a reward if the actual cost is below the estimated job cost. In return for taking the risk on its own estimate, the contractor is allowed a variable percentage of the direct job-cost for its fee. Furthermore, the project duration is usually specified and the contractor must abide by the deadline for completion. This type of contract allocates considerable risk for cost overruns to the owner, but also provides incentives to contractors to reduce costs as much as possible.

- Target Estimate Contract

This is another form of contract which specifies a penalty or reward to a contractor, depending on whether the actual cost is greater than or less than the contractor's estimated direct job cost. Usually, the percentages of savings or overrun to be shared by the owner and the contractor are predetermined and the project duration is specified in the contract. Bonuses or penalties may be stipulated for different project completion dates.

- Guaranteed Maximum Cost Contract

When the project scope is well defined, an owner may choose to ask the contractor to take all the risks, both in terms of actual project cost and project time. Any work change orders from the owner must be extremely minor if at all, since performance specifications are provided to the owner at the outset of construction. The owner and the contractor agree to a project cost guaranteed by the contractor as maximum. There may be or may not be additional provisions to share any savings if any in the contract. This type of contract is particularly suitable for *turnkey* operation.

- **Documents included in Contract Agreement:**

  -a simple document will identify the ff. basic elements: owner, general contractor, license number, worksite, description of work, contract price and payments, contract documents, material and labor, starting and completion dates, licensing and permits, subcontracts, work changes and warranties.

QUIZ 1:

1. It is a written document between a property owner and a general contractor, specifying the construction, renovation, alteration or other work to be done on the property owner's home or land.

2. It is a fee determined at the outset of the project.

3. Known as payments for any violation of labor laws and regulations on the job site.

4. Types of construction involving new technology or extremely pressing needs, the owner is sometimes forced to assume all risks of cost overruns.

5. Type of contract, the contractor agrees to a penalty if the actual cost exceeds the estimated job cost, or a reward if the actual cost is below the estimated job cost.

6. What is specification?

7. It is also known as the traditional fixed price contract.

8. This provision absolves an owner or a contractor for payment for costs due to "Acts of God" and other external events such as war or labor strikes.

9. This type of contract, the contractor will receive the actual direct job cost plus a fixed fee, and will have some incentive to complete the job quickly since its fee is fixed regardless of the duration of the project.

10. What is turnkey operation?

11. Why customized a specification?

12. Why are specification important to project management?

13. When is construction contract agreement needed?

II. Construction specification

A written document describing in detail the scope of work, materials to be used, methods of installation, and quality of workmanship for a parcel of work to be placed under contract.

- **Main types of Specification**
  - **Prescriptive**

- Provides details on the types of materials and installations needed to complete a project. Additionally, prescriptive specifications also describe how to measure installations to ensure that they were up to project quality and standards.

-Prescriptive specifications provide step-by-step details and instructions on how the types of materials to be used and the desired installation methods. However, these types of specs can be split into three subcategories:

- **General Provisions-**These provisions will reference national or state building codes and standards that must be complied with.
- **Required Products-**Lists the type of products and materials required, based on the performance and structural requirements.
- **Execution Procedures-** Details the methods of installation and how to measure quality or effectiveness.

  - **Performances**

- Describes the operational requirements. Fundamentally, the performance specifications should describe to the contractor what is needed for the final product and how it should essentially function once completed.

  - **Proprietary**

- Although not as common as prescriptive and performance, proprietary specifications are used if only one specific product can be used for an installation.

III. Construction Project Organization

- **Project Organization**

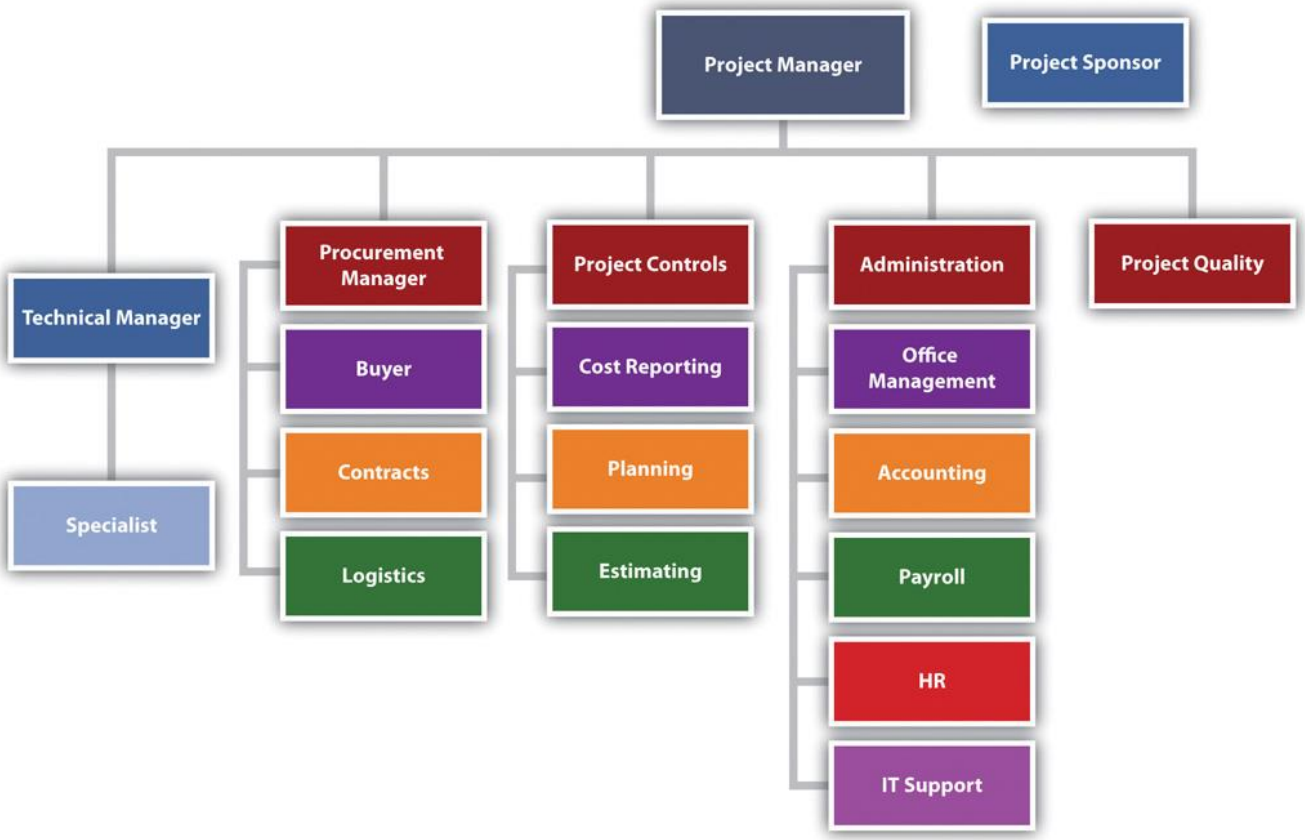
There is no single organizational approach to projects. Each project is organized to accomplish the work effectively and efficiently. Several factors influence the organizational approach to execute a project. The complexity profile of a project, the culture of the parent organization, the preferences of the project manager, the knowledge and skills of the team, and a parent organization with a project management office are examples of factors that influence the project's organization.

In developing the project organizational structure, the project manager considers the span of control for each manager. The span of control represents the number of people reporting to a manager. For example, the project manager does not want all the engineers on a project reporting to the engineering manager and assigns senior engineers to report to the engineering manager with other engineers reporting to the senior engineers.

The engineering manager can organize the engineering reporting structure so that the various engineering discipline managers would report to him or her. For example, the structural, electrical, and mechanical engineering team leaders would report to the engineer manager. On a larger, more complex project, the engineer manager may establish area team leaders and have the structural, electrical, and mechanical engineers report to an area team leader. If the project is geographically dispersed, with the engineering office staff in different cities working on the project, then structuring the engineering function by area provides better coordination and control.

- Most projects have similar functions that are important to successfully managing the project. Included among these are the following:
    - Sponsor
    - Controls
    - Project manager
    - Procurement
    - Technical management
    - Quality
    - Administration

FIGURE 1: ***Typical Project Organization***



On smaller projects, more than one function can be managed by one person. On larger projects, large teams may be needed to accomplish the work within the function.

ACTIVITY 2:

1. Identify the various functions represented on a project.

2. Analyze and evaluate the influence of organizational structure on project functions.

3. Design a project organizational chart for various project complexity profiles.

4. Why customized a specification?

5. Who handles construction specification?

- **Project Sponsor**

The project sponsor is outside the day-to-day operations of the project and has the organizational authority to provide resources and overcome barriers for the project. The project sponsor is typically a leader in the parent organization with an interest in the outcome of the project. As a leader in the parent organization, the project sponsor can provide input into the project scope and other documents that define project success. The guidance and support from the project sponsor enhance the ability of the project to successfully meet the parent organization's objectives.

- **Project Manager**

Project managers often have the breadth of responsibility associated with corporate chief executive officers (CEOs). The project manager facilitates the start-up of a project and develops the staff, resources, and work processes to accomplish the work of the project. He or she manages the project effectively and efficiently and oversees the closeout phase. Some projects are larger than major divisions of some organizations, with the project manager responsible for a larger budget and managing more risk than most of the organizational leaders. A mining company that builds a new mine in South Africa, an automobile manufacturer that creates a new truck design, and a pharmaceutical company that moves a new drug from testing to production are examples of projects that may consume more resources in a given year than any of the organization's operating divisions.

The function of the project manager can vary depending on the complexity profile and the organizational structure. Defining and managing client expectations and start-up activities, developing the scope, and managing change are functions of the project manager. On some projects, the project manager may provide direction to the technical team on the project. On other projects, the technical leadership might come from the technical division of the parent organization.

Although the functional responsibilities of the project manager may vary, the primary role is consistent on every project. The primary role of the project manager is to lead, to provide a vision of success, to connect everyone involved in the project to that vision, and to provide the means and methods to achieve success. The project manager creates a goal-directed and time-focused project culture. The project manager provides leadership.

- **Project Control**

In general, project controls are both the planning function and the function that tracks progress against the plan. Project control provides critical information to all the other functions of the project and works closely with the project manager to evaluate the cost and scheduling impact of various options during the life of a project.

Sometimes accounting functions such as payroll, budgeting, and cash management are included within project controls. On larger projects, accounting functions are typically separate because the accounting culture tracks expenses to the nearest penny, and cost estimating and tracking by project controls can often be off by hundreds and sometimes thousands of dollars. The lack of definitive information necessitates the development of cost estimates within ranges that are often inconsistent with accounting practices. Separating these two functions allows each to operate within their own accuracy comfort zone. The following are typical activities included within the project controls function:

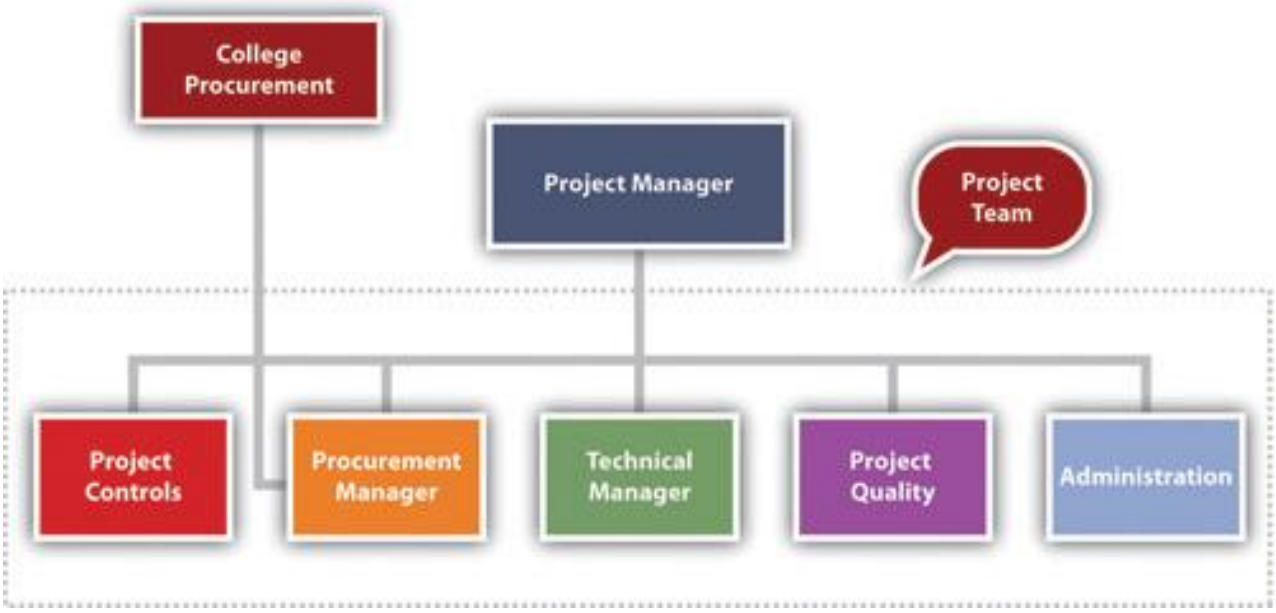
- Estimating
- Tracking costs
- Analyzing trends and making projections
- Planning and scheduling
- Managing change
- Tracking progress against schedule

The project controls team gathers this information from all the functions on the project and develops reports that enable each functional manager to understand the project plan and progress against the plan at both the project level and the functional level. On large complex projects, some project managers will assign project controls professionals to work within the major functions as well as the project management office. This approach allows each function to plan and track the function's work in more detail. The project controls manager then coordinates activities across functions.

- Project Procurement

The approach to purchasing the supplies and equipment needed by the project is related to the complexity profile of the project. A small project with a low complexity level may be able to use the procurement services of the parent organization. In an organization where project resources reside in various departments, the departments may provide the supplies and equipment each team member of the project may need.

FIGURE 2:



The procurement manager is part of the project team.

On larger, more complex projects, the procurement team has several responsibilities. The team is responsible for procuring the supplies and equipment (such as office supplies and computers) needed for the project team and the supplies and equipment (such as the training equipment) needed to execute the project. On a typical construction project, the procurement team would rent a construction trailer, office supplies, and computers for the project team to establish a construction office at the construction site. The procurement team would also purchase the concrete, rebar, steel, and other material needed to construct the building.

- **Commodity Procurement**

The largest number of purchased items for most projects are commodity items. Commodities are items that can be bought off the shelf with no special modification for the project. These items are typically bid and the lowest prices that can meet the schedule of the project will win the contract. The procurement team assures the company that wins the bid can perform to the contact specifications and then monitors the progress of the company in meeting the projects requirements. Concrete for the project and the cranes leased to the project are examples of commodities. The key to success in managing commodity suppliers is the process for developing the bids and evaluating and awarding the contracts.

- **Procurement from Vendors**

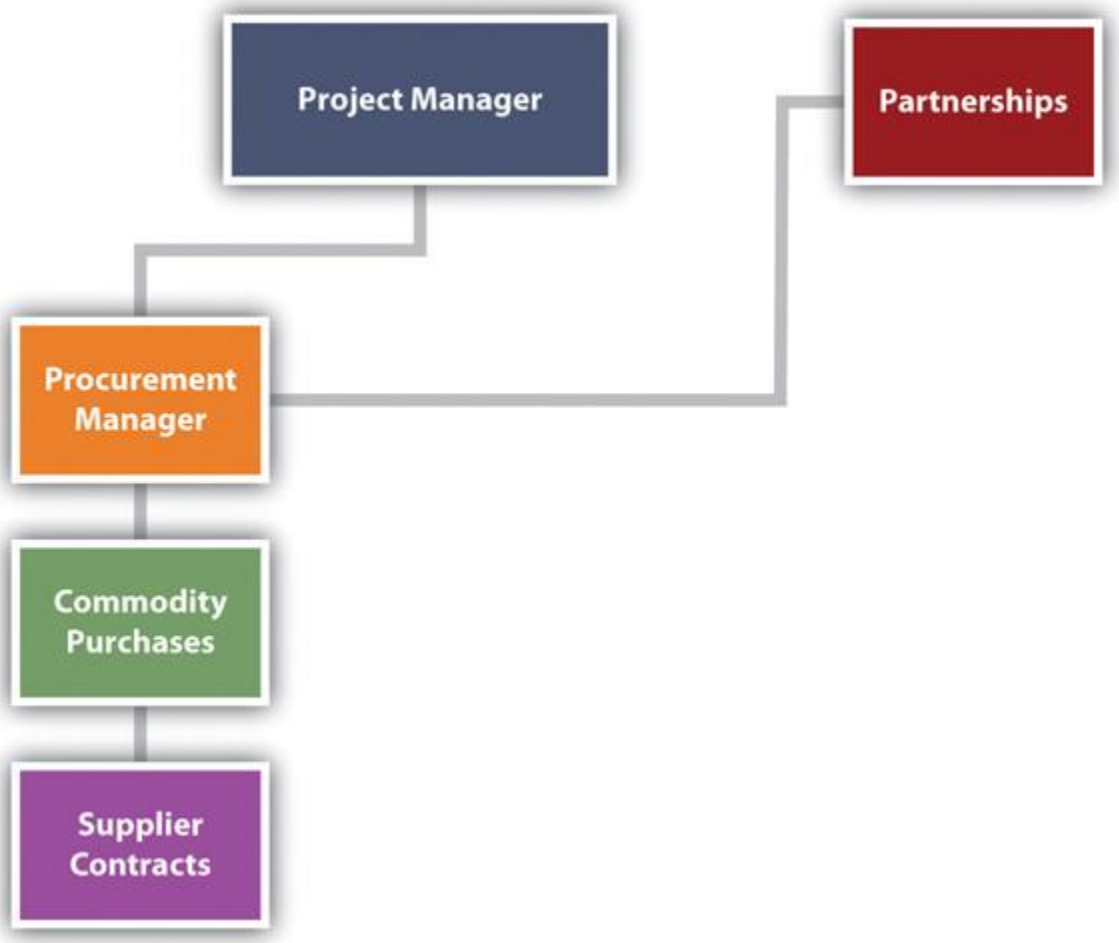
The second type of relationship is the vendor relationship. The terms supplier and vendor are often used interchangeably. In this text, suppliers provide commodities, and vendors provide custom services or goods. Suppliers bid on specialized equipment for the project. Engineers will specify the performance requirements of the equipment, and suppliers that have equipment that meets the requirements will bid on the project. The engineering team will assist in the evaluation of the bids to assure compliance with specifications. The lowest bid may not win the contract. Sometimes the long-term maintenance costs and reliability of the equipment may indicate a high price for the equipment. The key to success is the development of clear performance specifications, good communication with potential bidders to allow bidders to develop innovative concepts for meeting the performance requirements, and a bidding process that focuses on the goals of the project.

- **Partnerships**

The third type of project procurement relationship is the partnership. Sometimes the partnership is legally defined as a partnership, and sometimes the success of each partner is so closely tied together that the relationship operates as a partnership. On the South American project, the project team partnered with an Argentinean construction company to access the local construction practices and relationship with local vendors. This was a legal partnership with shared profits. The partner also designed and procured some large mining equipment on which the success of the project and the company building the mining equipment depended. With this type of relationship, a senior manager on the

project is assigned to coordinate activities with the partner, and processes are put in place to develop shared goals, align work processes, and manage change.

FIGURE 3: ***Procurement Manager Relationships***



- **Technical Management**

The technical management on the project is the management of the technology inherent in the project—not the technology used by the team to manage the project. The technical complexity on a project can vary significantly. The technological challenges required to build a bridge to span a five-hundred-meter canyon are significantly different from those required to span a five-thousand-meter body of water. The technological complexity of the project will influence the organizational approach to the project. The technological complexity for a project reflects two aspects: the newness of the technology and the team's familiarity with the technology. The newness refers to the degree to which

the technology has been accepted in the industry. The more accepted the technology is in the industry usually means that more knowledge and experience will be available to the team. Familiarity refers to the experience the project team has with the technology. The less familiarity the team has with the technology, the more energy and resources the team will expend on managing the technological aspect of the project. For projects with high levels of project technology, a specialist may be hired to advise the technology manager.

- **Project Quality**

Project quality is often part of the technical manager's responsibility. On large projects or projects with a high degree of technical complexity, the quality is sometimes a separate function reporting to the project manager. The project quality manager focuses on the quality of the project work processes and not the quality of the client's product. For example, if the project is to design and construct an automobile factory, the quality manager focuses on the project work processes and meeting the technical specification of the equipment installed by the project team. The project quality manager is not responsible for the quality of the car the plant produces. If the plant functions to the defined project specifications, the quality of the plant output is the responsibility of the plant quality department, and it may take several months for the plant to refine the work processes to meet the design specifications of the car.

On a construction project, the quality manager may test steel welders to assure the welders have the skills and that the welds meet project specifications. On a training project, the quality manager may review the training curriculum and the qualification of the instructors to assure the training provides the knowledge and skills specified by the client. On a drug development project, the quality manager may develop processes to assure the water and other raw material meet specifications and every process in the development process is properly documented.

- **Project Administration**

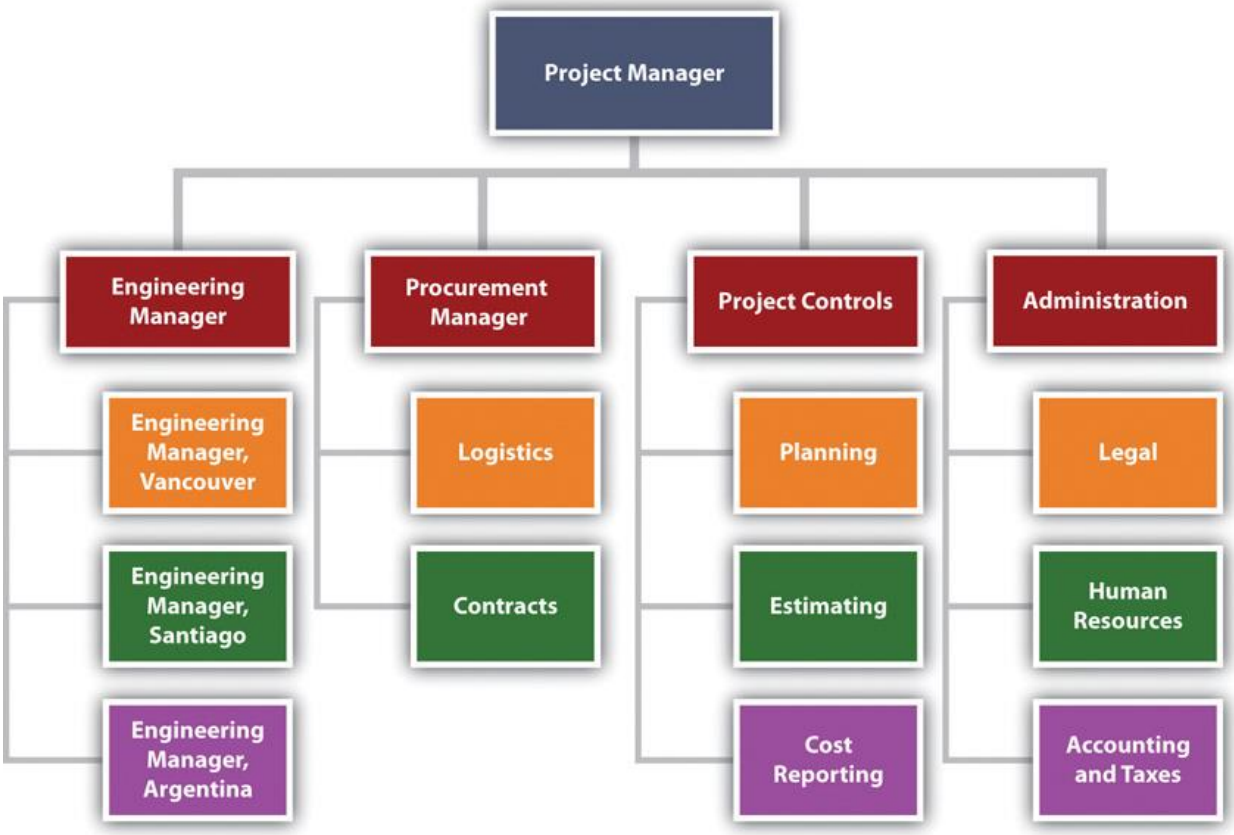
The administrative function provides project specific support such as the following:

- Accounting services
- Legal services
- Property management
- Human resources (HR) management
- Other support functions found in most organizations

In most organizations, support for these functions is provided by the parent organization. For example, people assigned to the project will get human resources (HR) support from the HR department of the parent organization. Salary, benefits, and HR policies for employees assigned to the project will be supported out of the HR department. The parent organization will provide accounting functions such as determining the cost of cash, taxes, year-end project reports, and property disposal at the end of the project.

The project manager on smaller, less complex projects will have sufficient knowledge about these issues to coordinate with the parent organization's functional leaders. On more complex projects, the project may have an administrative manager responsible for coordinating the administrative functions of the projects. On larger, more complex projects, an administrative function may be established as part of the project team, with many of the functions assigning a resource to the project. In all cases, the administrative function on a project is closely related to the legal and organizational responsibilities of the parent organization and close coordination is important.

Figure 4: ***Organization for Major International Project***



SUMMARY:

- Key functions on a project include sponsor, project manager, controls, procurement, technical, quality, and administration.
- The project sponsor has the organizational authority to provide guidance and resources and can overcome barriers for the project.
- The project manager is the project leader with broad responsibilities for all phases of the project and for meeting project goals and client expectations.
- The project controls manager is responsible for controlling the project processes, including cost estimating and tracking, developing schedules, tracking progress against schedules, managing changes to the schedule or budget, and analyzing trends.
- The procurement manager is responsible for obtaining the services and materials needed to complete the project. This is accomplished by purchasing commodities, managing contractors who provide services and products, and working with partners.
- The technical manager deals with the issues related to the technology of the project.
- The quality manager monitors the project's processes—not the quality of the product of the project—and takes steps to assure they are done correctly and meet specifications.
- Project administration manages accounting, legal, property, and human resources.

QUIZ 3a:

1. Materials or services whose quality is standardized and that are usually purchased based on lowest price are _____.

2. Major components of a project that are specialized and that require the provider to help with solving problems and share in the profits are provided by _____

3. Worker benefits would be managed by the _____ function.

4. Tracking costs and comparing them to the project budget is handled by the _____ function.

5. Buying concrete for a bridge project would be handled by the _____ function.

6. Checking to see that the work performed on the project is done consistently and up to specifications is managed by the _____ function.

7. The number of people who report to a manager is referred to as the _____ __ _____ (three words).

8. If employees are responsible for estimating costs, to whom would they report?

9. Refer to Figure 3."Procurement Manager Relationships". How do partnerships affect the complexity of the project? Describe an example of a situation where the partnership could affect the complexity of the project.

10. How is procurement from suppliers different from buying commodities?

11. Refer to figure 2.. To whom does the procurement manager report? Provide an example of a situation where this reporting relationship might increase the complexity of the project.

QUIZ 3b:

Project Organization

Refer to the descriptions of the project functions and determine which manager would take care of each of the following problems. If you think the problem requires the attention of more than one function, explain why.

1. One of the project team members has filed a sexual harassment suit against another team member of equal rank. _____

2. A contractor is installing equipment that is substandard. _____

3. The computer software used to make a step improvement in the client's operations has a significant bug in it. _____

4. The client wants to use higher-quality materials in the project than was originally agreed on. _____

5. Your organization has announced budget cuts but you cannot afford to lose anyone at this crucial stage in the project. _____

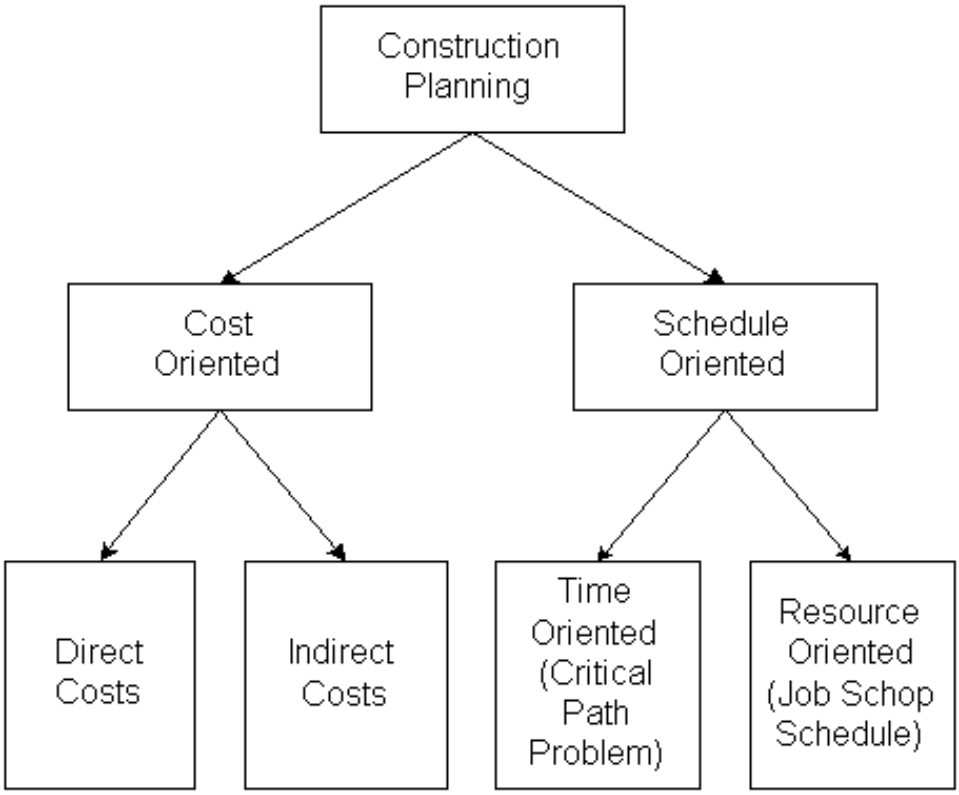
6. A contractor has complained that the procurement manager has a conflict of interest with a competing contractor. _____

IV. Planning and Scheduling

❖ Construction Planning

Construction planning is a fundamental and challenging activity in the management and execution of construction projects. It involves the choice of technology, the definition of work tasks, the estimation of the required resources and durations for individual tasks, and the identification of any interactions among the different work tasks. A good construction plan is the basis for developing the budget and the schedule for work. Developing the construction plan is a critical task in the management of construction, even if the plan is not written or otherwise formally recorded. In addition to these technical aspects of construction planning, it may also be necessary to make organizational decisions about the relationships between project participants and even which organizations to include in a project. For example, the extent to which sub-contractors will be used on a project is often determined during construction planning.

Alternative Emphases in Construction Planning



❖ **Scheduling** is when a plan is assigned specific dates and a chronological order to the tasks, so that a plan can be put into action. These schedules need to include

contingencies for variances in the plan. This reflects the 'when' of a project, with the assigning of appropriate resources to get it done on time.

V. Project Management

- **Project-** A project is an interrelated set of activities that has a definite starting and ending point and that results in a unique product or service. Project management
- **Project management-** is a scientific way of planning, implementing, monitoring & controlling the various aspects of a project such as time, money, materials, manpower & other resources.

Methods used for network planning are:

-CPM
-PERT

Managing a project with network planning methods involves four steps:

1. Describing the Project.
2. Diagramming the Network.
3. Estimating time of completion.
4. Monitoring Project Progress.

❖ **Rules of Network Construction**

1. Each activity is represented by one arrow
2. An activity can begin only when all its predecessors are done
3. Length and bearing of arrows is of no consequence
4. Arrow direction indicates general progression in time – tail events represent start while head events represent end of activities
5. Events are identified by numbers while activities are represented by their starting and ending events
6. A network should have only one initial and one final node
7. Introduce as few dummy activities as may be necessary 8. Looping is not permitted

❖ **CPM**

-Critical path is a sequence of activity between a project's start and finish that takes the longest time to complete
- Critical path method is based on mathematical calculations and it is used for scheduling project activities.
- In 1950, Critical path method (CPM) was developed by Kelly and Walker to assist in building and maintains of chemical plants.
- The initial critical path method was used for managing plant maintenance projects.
- Critical path is the sequential activities from start to the end of a project. Although many projects have only one critical path, some projects may have more than one critical paths depending on the flow logic used in the project
- The essential technique for using CPM is to construct a model of the project that includes the following:

- A list of all activities required to complete the project (typically categorized within a work breakdown structure ’
- The time (duration) that each activity will take to completion,
- ’ The dependencies between the activities

Terminologies used in CPM

In order to explain the purpose, structure and operation of CPM, it is helpful to define the following terms:

Activity: An activity carries the arrow symbol. This represent a task or subproject that uses time or resources

Event- A node (an event), denoted by a circle, marks the start and completion of an activity, which contain a number that helps to identify its location. For example activity A can be drawn as:

Dummy Activity: An activity, which is used to maintain the pre-defined precedence relationship only during the construction of the project network, is called a dummy activity. Dummy activity is represented by a dotted arrow and does not consume any time and resource.

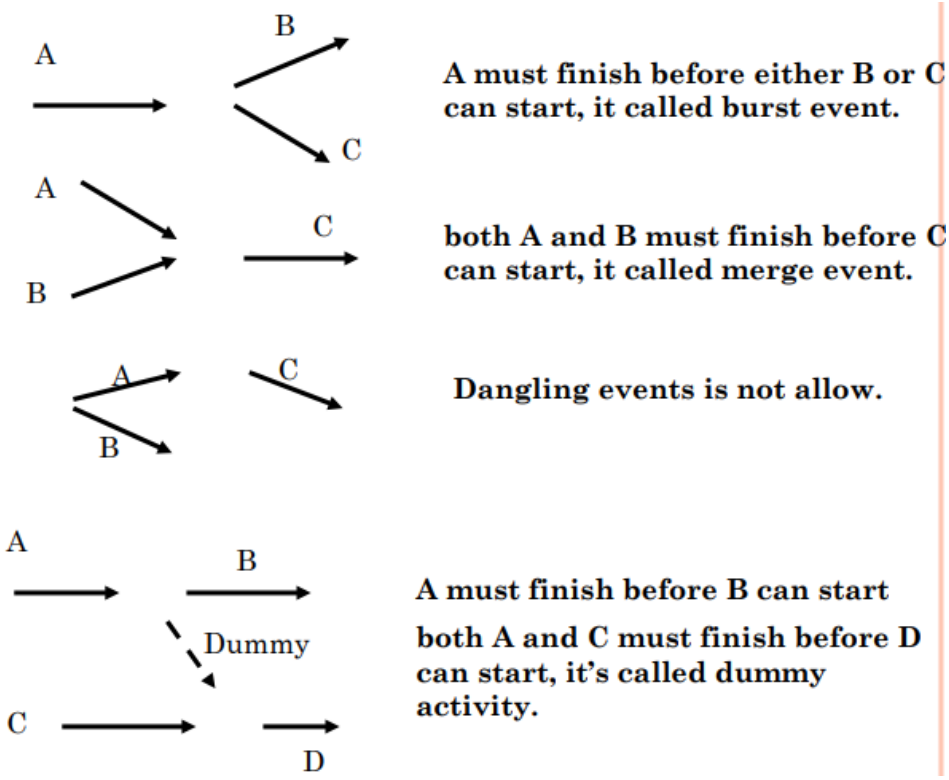
Parallel activity: There are two activity which being at same event and end at same event.this activities are called parallel activity.

Not allowed….. ’

Path: A path is a series of adjacent activities leading from one event to another. ’

Critical path: A critical path is the sequence of critical activities that forms a continuous path between the start of a project and its completion.

- **Situations in network diagram**



Forward pass:

- The Early Start and Early Finish Time Calculated by moving Forward Through the Network.

-Consider Maximum.

Backward pass:

-The Latest Start and Latest Finish Time Calculated by moving Backward Through the Network.

-Consider Minimum

Float activity:

-Float activity For an Activity is The Difference between its Earliest and Latest Start Time or Earliest and Latest Finish Time.

- **Steps in Critical Path Method**
    - Step 1: Make a forward pass through the network as follows: For each activity i beginning at the Start node,

compute:
Earliest Start Time (ES) = the maximum of the earliest finish times of all activities immediately preceding activity i. (This is 0 for an activity with no predecessors.). This is the earliest time an activity can begin without violation of immediate predecessor requirements.
Earliest Finish Time (Ef) = (Earliest Start Time) + (Time to complete activity i. This represent the earliest time at which an activity can end.
The project completion time is the maximum of the Earliest Finish Times at the Finish node.

- Step 2: Make a backwards pass through the network as follows:

Move sequentially backwards from the Finish node to the Start node. At a given node, j, consider all activities ending at node j. For each of these activities, (i,j), compute:

Latest Finish Time (LF) = the minimum of the latest start times beginning at node j. (For node N, this is the project completion time.). This is the latest time an activity can end without delaying the entire project.

Latest Start Time (LS) = (Latest Finish Time) - (Time to complete activity (i,j)). This is the latest time an activity can begin without delaying the entire project.

Step 3: Calculate the float time for each activity by:

float = (Latest Start) - (Earliest Start),

or

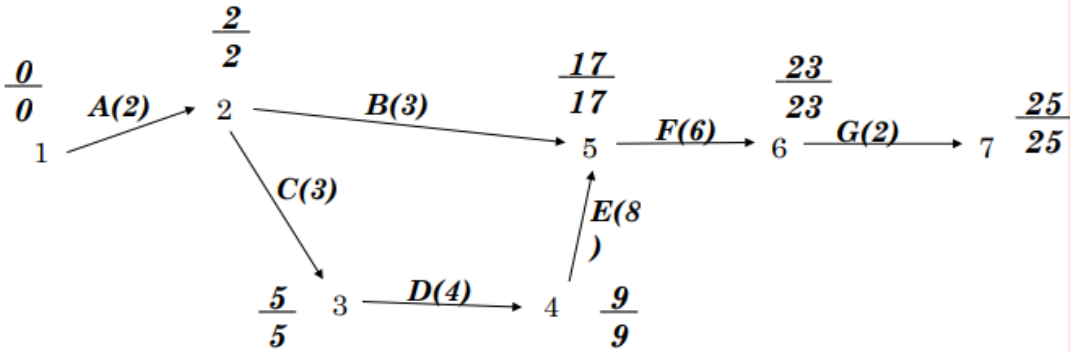
= (Latest Finish)-(EarliesFinish).

A critical path is a path of activities, from the Start node to the Finish node, with 0 float times.

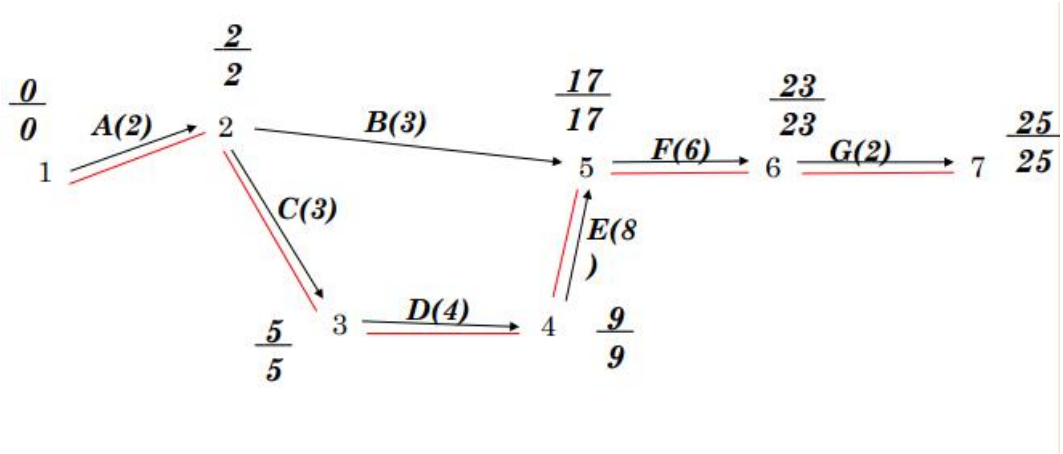
Example

1. Construct the CPM Network using the details below and determine the critical path

Activity	Immediate predecessors	Completion Time (week)
A	-	2
B	A	3
C	A	3
D	C	4
E	D	8
F	B,E	6
G	F	2



Activity	Tme	Earliest Start (ES)	Earliest Finish (EF)	Latest Start (LS)	Latest finish (LF)	Slack (LS-ES)	Critical path
A	2	0	2	0	2	0	Yes
B	3	2	5	14	17	12	No
C	3	2	5	2	5	0	Yes
D	4	5	9	5	9	0	Yes
E	8	9	17	9	17	0	Yes
F	6	17	23	17	23	0	Yes
G	2	23	25	23	25	0	Yes



Critical Path: - Cp = 1 - 2 – 3 - 4 – 5 – 6 – 7 = A – C -D - E - F - G = 2 + 3 + 4 + 8 + 6 + 2 = 25

- **Benefits of CPM** ′
  - Useful at many stages of project management
  - Mathematically simple ′
  - Give critical path and float time ′
  - Provide project documentation
  - ′Useful in monitoring costs ′
  - Visual representation
- **Limitations to CPM**
  - Specified precedence relationship ′
  - Activity time estimates are subjective and depend on judgment ′
  - Can be more difficult understand ten grant charts ′
  - The time needed for tasks is not as clear as with grant charts

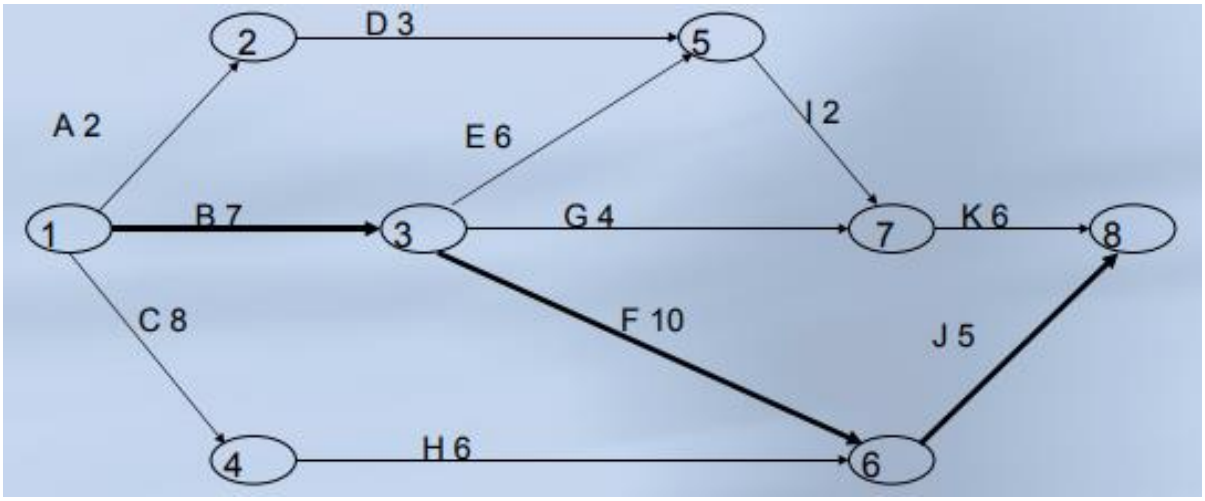
CRITICAL PATH

EXAMPLE 2: Information on the activities required for a project is as follows:

Name	A	B	C	D	E	F	G	H	I	J	K
Activities Node	1-2	1-3	1-4	2-5	3-5	3-6	3-7	4-6	5-7	6-8	7-8
Duration (Days)	2	7	8	3	6	10	4	6	2	5	6

- Draw the network and calculate the earliest start (ES), earliest finish(EF), latest start(LS), and latest finish(LF) times of each of the activities.
- Critical Path: 1-3-6-8
- Critical Activities: B F J
- Project Duration: 22 days

- Non-critical Activities: A C E G H I K



- **FLOATS**
    - **Total float** is the amount of time by which an activity may be delayed without delaying the project completion
      Caution: interpret total floats of activities carefully - all can not be used independently
    - **Free float** is that part of total float which can be used without affecting floats of the succeeding activities
    - The part of total float which is not free is called **interfering float**
    - **Independent float** is the amount of time which can be used without affecting the head and the tail events Total Float ≥ Free Float ≥ Independent Float
- **CALCULATION OF FLOATS**

Total float
= Latest start time of the activity – Earliest start time of the activity
Free float
= Total float – Head event slack
= Earliest start time of the next activity – Earliest completion time of the activity
Interfering float
= Total float – Free float
Independent float
= Earliest start time of the next activity – Latest finish time of the preceding activity – Duration of the activity
= Free float – Tail event slack, or zero, whichever is higher

i - j	t	ES	EF	LS	LF	TF	IF	FF	InF
1-2	2	0	2	9	11	9	9	0	0
1-3	7	0	7	0	7	0	0	0	0
1-4	8	0	8	3	11	3	3	0	0
2-5	3	2	5	11	14	9	1	8	0
3-5	6	7	13	8	14	1	1	0	0
3-6	10	7	17	7	17	0	0	0	0
3-7	4	7	11	12	16	5	1	4	4
4-6	6	8	14	11	17	3	0	3	0
5-7	2	13	1	14	16	1	1	0	0
6-8	5	17	22	17	22	0	0	0	0
7-8	6	15	21	16	22	1	0	1	0

QUIZ 4:

1. Construct a network diagram from the following information:

   a.

Activity	Precedes	Estimated Time (weeks)
a	b	15
b	c, d	13
c	e	8
d	end	5
e	end	3

b.

Activity	Precedes	Estimated Time (weeks)
f	g, h	10
g	I, j	10
h	j	8
i	end	6
j	l	12
k	end	7

2. Draw the following network:

a. G follows but precede H
b. G follows D but precede J
c. M follows H but precede L
d. K follows A but precede L
e. F follows A
f. A and D start at the same time.
g. J and L terminate at the same time

❖ **PERT**

Program (Project) Evaluation and Review Technique (PERT): is a project management tool used to schedule, organize, and coordinate tasks within a project. It is basically a method to analyze the tasks involved in completing a given project, especially the time needed to complete each task, and to identify the minimum time needed to complete the total project.

- PERT is used when activity times are uncertain.
  – Determine the duration of the project.
  – Decision making under risk ("P" for probabilistic)
- Determine the duration of the project
  OPTIMISTIC TIME: Best time if everything goes perfectly
  • **REALISTIC TIME:** Most likely time
  • **PESSIMISTIC TIME:** A worst-case situation
  Expected Time = $\frac{B+4M+P}{6}$

EXAMPLE:

For excavation activity let:

B=12days

M=18days

P=60

What is the expected time for this activity?

Sol.

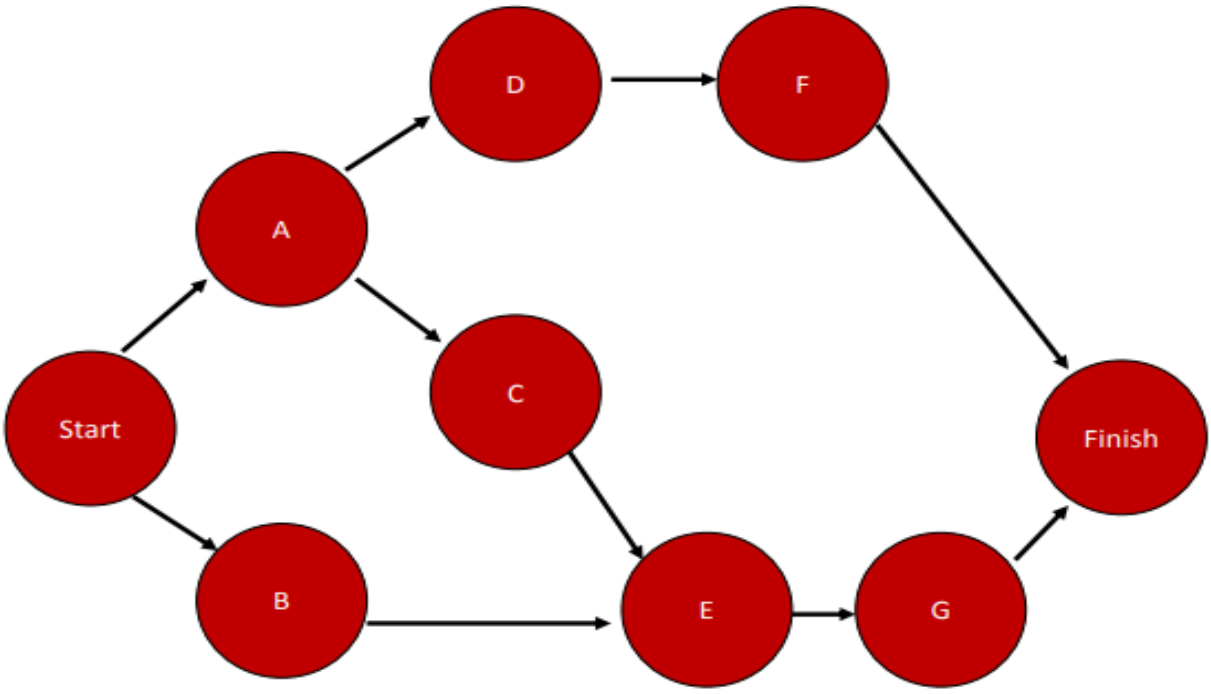
Expected Time=$\frac{12+4(18)+60}{6}$

=24 days

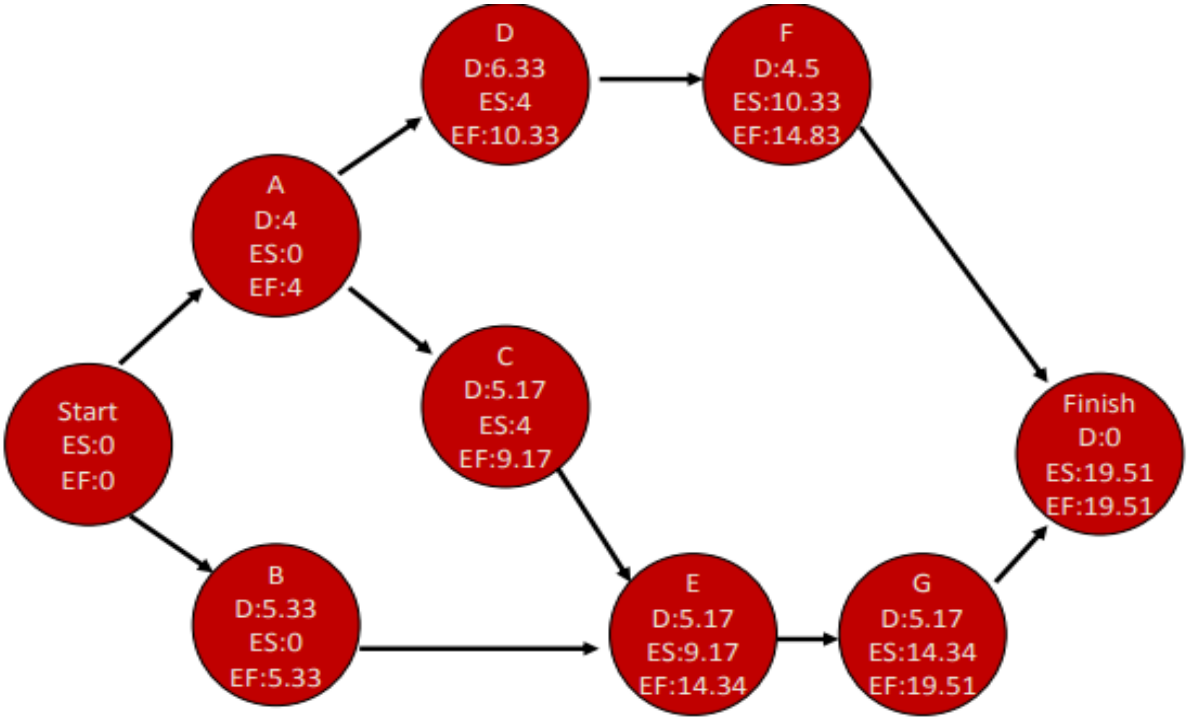
Determine the duration of the project

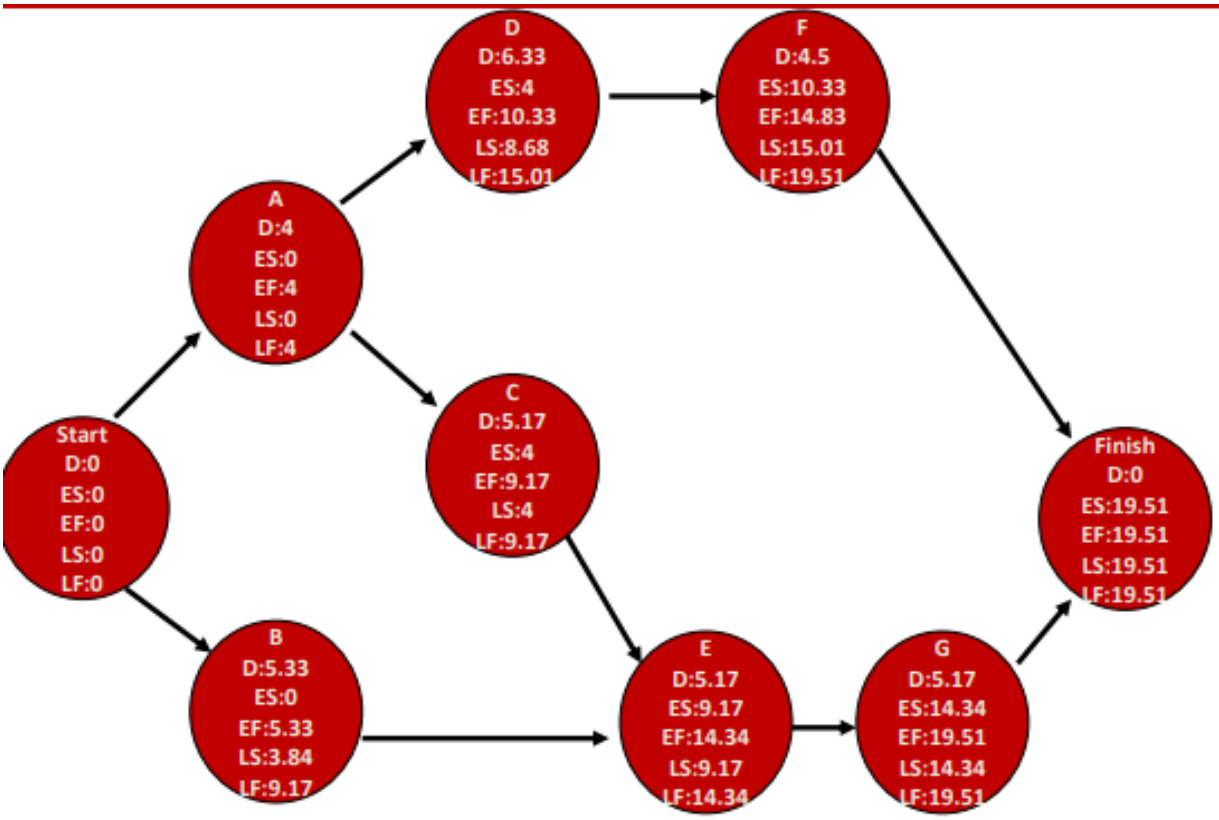
Activity	Predecessors	Optimistic (B)	Normal (m)	Pessimistic (P)	Te (B+4m+P)/6
A	__	2	4	6	4.00
B	__	3	5	9	5.33
C	A	4	5	7	5.17
D	A	4	6	10	6.33
E	A, B	4	5	7	5.17
F	D	3	4	8	4.50
G	E	3	5	8	5.17

Determine the duration of the project



Determine the duration of the project





Critical Path

Critical Path: A-C-E-G

- Path A-D-F = 14.83 work days
- Path A-C-E-G = 19.51 work days
- Path B-E-G = 15.67 work days

ACTIVITY	LF-EF	TOTAL
A	4-4	0
B	9.17-5.33	3.84
C	9.17-9.17	0
D	15.01-10.33	4.68
E	14.34-14.34	0
F	19.51-14.83	4.68
G	19.51-19.51	0

❖ Advantages of PERT

- Expected project completion time.
- Probability of completion before a specified date.
- The critical path activities that directly impact the completion time.
- The activities that have slack time and that can lend resources to critical path activities.
- Activity start and end dates.

❖ LIMITATIONS

- The PERT Formula Requires Too Much Work.
- The network charts tend to be large and unwieldy.
- Calculating the time estimates is very complex for all the activities.
- Updating of the project is time consuming and requires high costs.
- Emphasis is laid only on time factors and cost factors are neglected.

Summary for PERT/CPM

Guidelines for network diagram

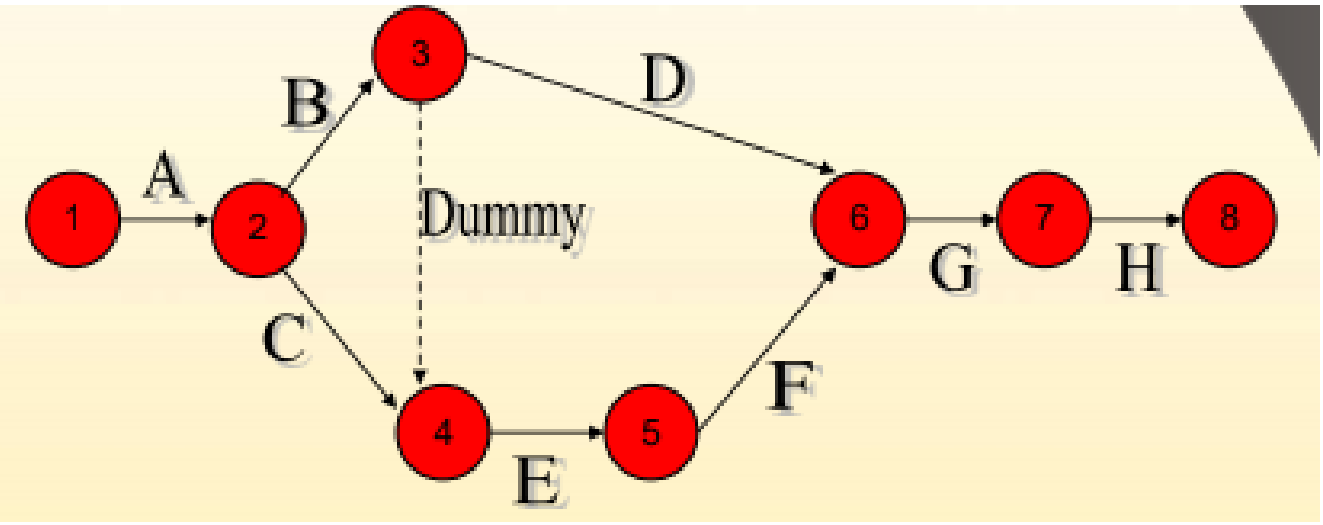
1. Before an activity can begin, its preceding activities must be completed.
2. Arrows indicate logical precedence.
3. Flow of the diagram is from left to right.
4. Arrows should not intersect.
5. Dangling should be avoided.

APPRAOCHES FOR NETWORK DIAGRAM

ACTIVITY ON ARC(AOA):

-Uses arcs to represent activities and nodes to represent events.

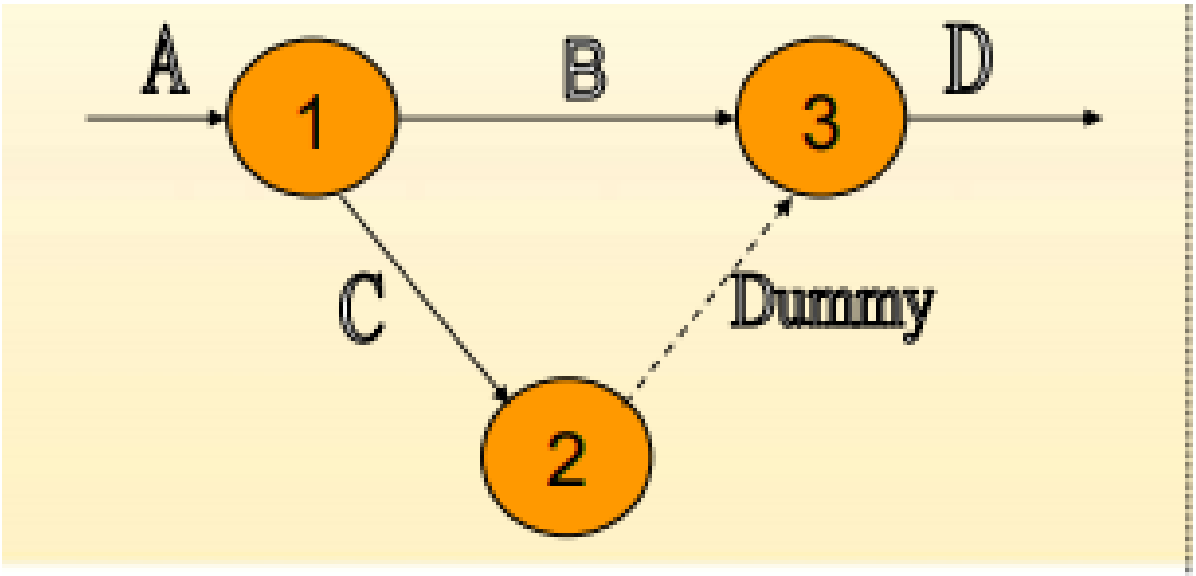
-It is Event Oriented.



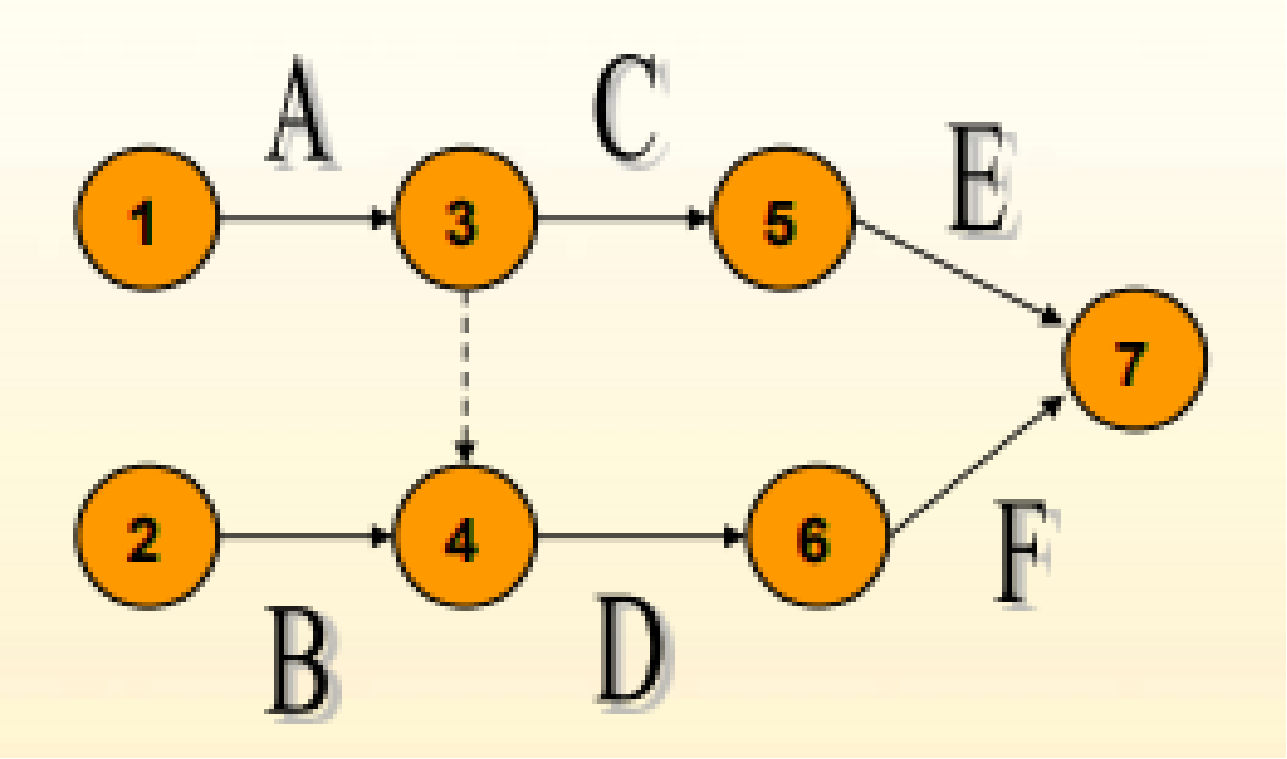
DUMMY ACTIVITY-AOA approach requires the addition of a Dummy Activity to clarify the precedence relationships between the two activities. It is a zero-time activity and consumes no resources.

Dummy Activity is used in two situations:

1) When two or more activities start and end at the same nodes

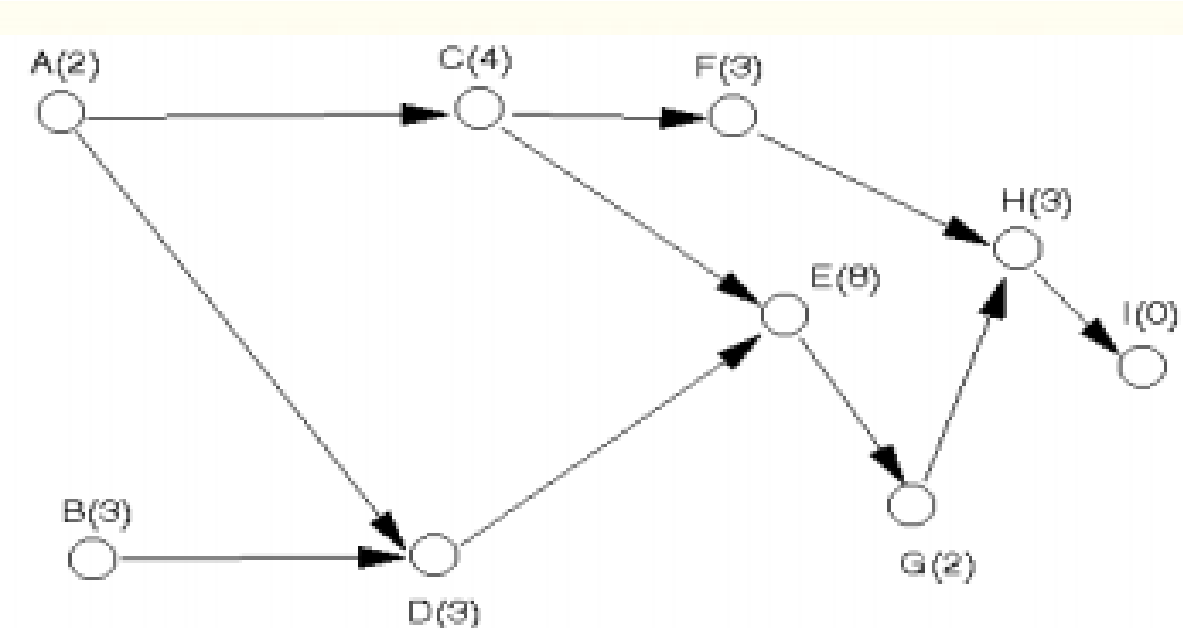


2) When two or more activities share the same precedence activity but not all the precedence are shared.



ACTIVITY ON NODE(AON):

- Uses nodes to represent activities and arcs indicate precedence relationships between them. It is Activity Oriented.



ESTIMATING TIME OF COMPLETION

Planning the schedule of the project

Time estimates include:

1) Total time for completion.

2) ES- Earliest start time: the earliest time at which the activity can start given that its precedent activities must be completed first.

3) EF-Earliest finish time: equals to the earliest start time for the activity plus the time required to complete the activity.

4) LF- Latest finish time: the latest time in which the activity can be completed without delaying the project.

5) LS- Latest start time: equal to the latest finish time minus the time required to complete the activity.

6) FORWARD PASS: The early start and early finish times are calculated by moving forward through the network and considering the predecessor activities Considers maximum

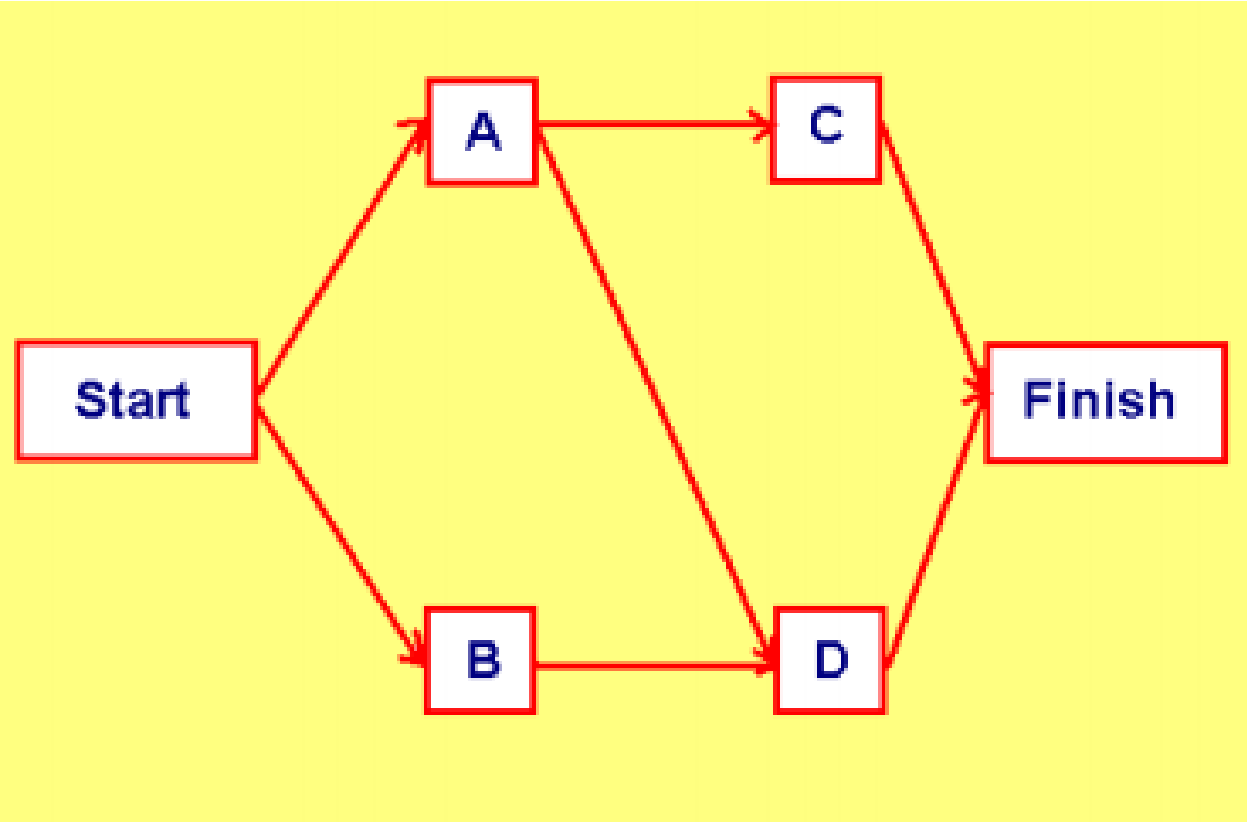
7) BACKWARD PASS: The latest start and finish times are calculated by moving backward through the network. Considers minimum

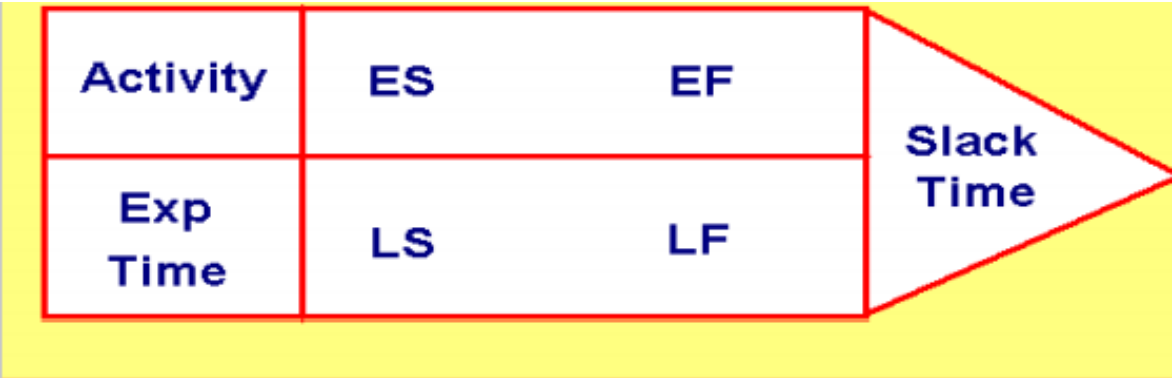
8) SLACK TIME: Slack time for an activity is the difference between its earliest and latest start time or between the earliest and latest finish time. Critical path is the path of activities having zero Slack time.

A Simple Project:

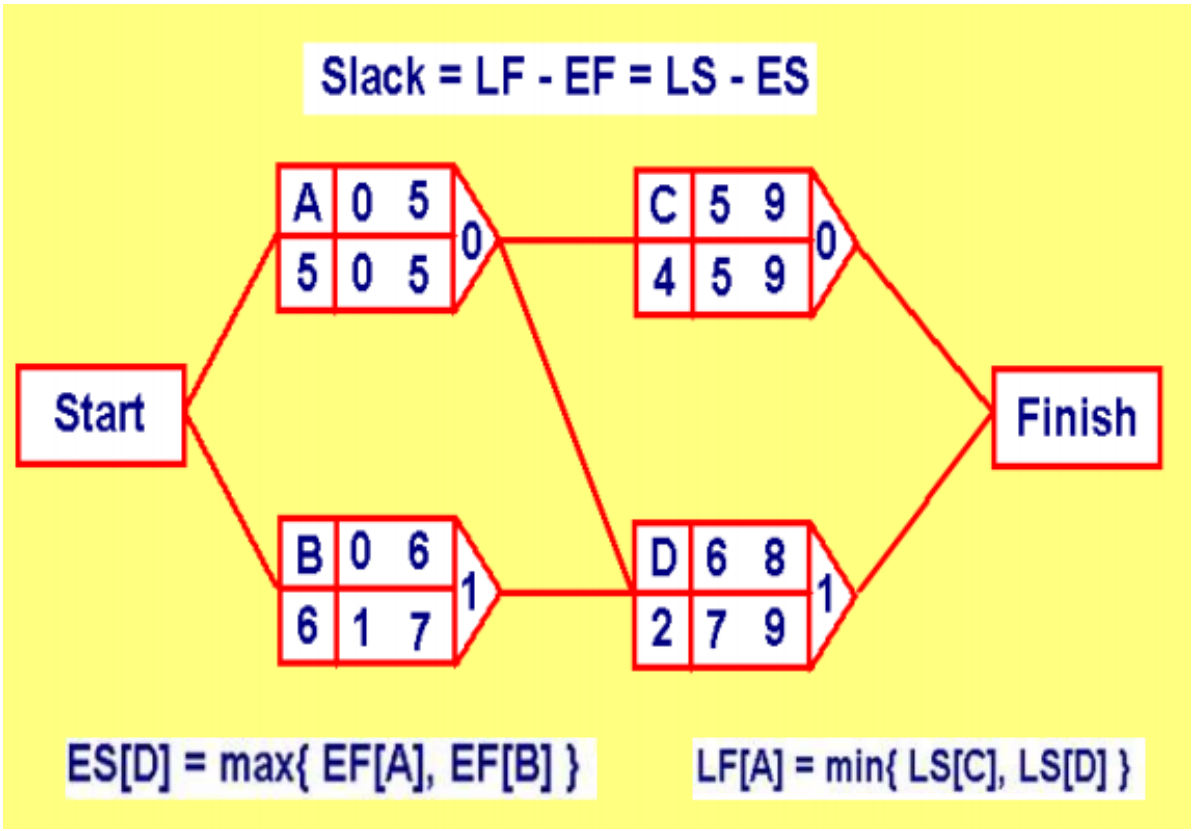
ACTIVITY	IMMEDIATE PREDECESSOR	TIME EXPECTED
A	**-**	**5**
B	**-**	**6**
C	**A**	**4**
D	**A, B**	**2**

Precedence Diagram





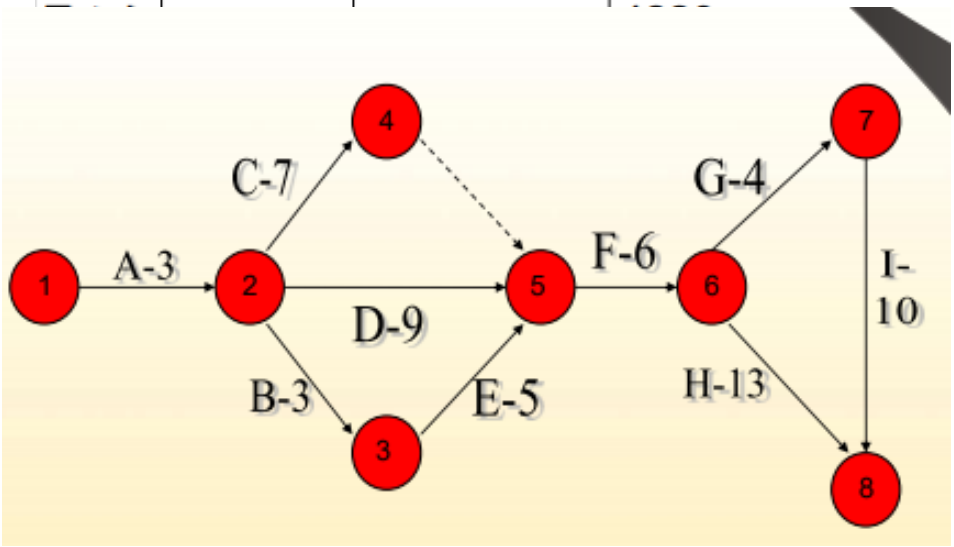
ES	Earliest Starting (time)
EF	Earliest Finishing
LS	Latest Starting
LF	Latest Finishing
Slack	Difference Time



STEPS IN DETERMINING CRITICAL PATH

- Specify the individual activities.
- Determine the sequence of the activities.
- Draw the network diagram.
- Estimate the activity completion time.
- Identify the critical path.
- Update the CPM diagram

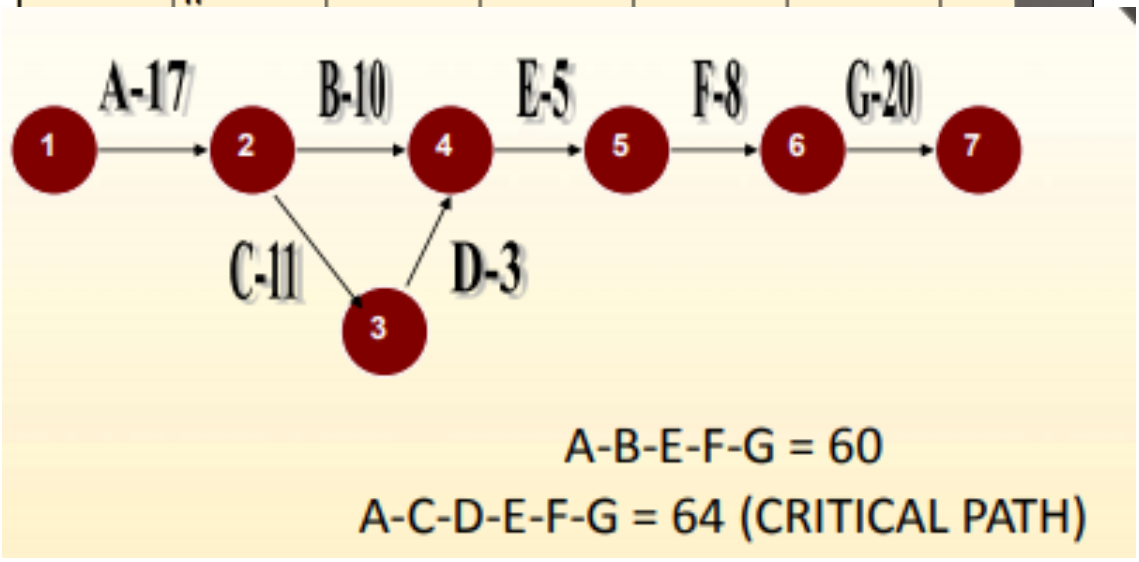
Activity	Precedence	Normal time (week)	Normal Cost (Rs)
A	-	3	300
B	A	3	30
C	A	7	420
D	A	9	720
E	D	5	250
F	B,C,E	6	320
G	F	4	400
H	F	13	780
I	G	10	1000



STEPS IN PERT

1. Identify the specific activities.
2. Determine proper sequence of the activities.
3. Construct the network diagram.
4. Estimate the time required for each activity.
5. Determine the critical path.
6. Update the PERT chart.

Activity	Description	Precedence	Optimistic time	Most Likely time	Pessimistic time	Expected time
A	Initial design	-	12	16	26	17
B	Survey market	A	6	9	18	10
C	Build prototype	A	8	10	18	11
D	Test prototype	C	2	3	4	3
E	Redesigning	B,D	3	4	11	5
F	Market testing	E	6	8	10	8
G	Set up production	F	15	20	25	20



A-B-E-F-G = 60

A-C-D-E-F-G = 64 (CRITICAL PATH)

Difference between CPM & PERT

CPM	PERT
CPM works with fixed deterministic time	PERT works with probabilistic time
CPM is useful for repetitive and non-complex projects with a certain degree of time estimates.	PERT is useful for non-repetitive and complex projects with uncertain time estimates.
CPM includes time-cost trade off.	PERT is restricted to time variable.
CPM- for construction projects.	PERT- used for R&D programs.

QUIZ 5:

Tabulate the Result of ES-EF and LS-LF

Activity	Est'd time	Start		Finish		Float		Critical Activity
		ES	LS	EF	LF	total	Free	
1-2	8	0	0	8	8	0	0	*
1-3	5	0	0	5	5	0	0	*
1-4	6	0	14	6	20	14	0	
2-6	7	8	8	15	15	0	0	*
3-4	0	5	20	5	20	15	1	
3-6	10	5	5	15	15	0	0	*
4-5	5	6	22	11	27	16	0	
4-7	7	6	20	13	27	14	8	
5-7	0	11	27	11	27	16	10	
6-7	6	15	21	21	27	6	0	
6-8	9	15	15	24	24	0	0	*
6-10	12	15	20	27	32	5	5	
7-9	3	21	27	24	30	6	0	
8-10	8	24	24	32	32	0	0	*
9-10	2	24	30	26	32	6	6	

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